Planning for nuclear security

Design Basis Threats and physical protection systems

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Design Basis Threats (DBTs) are summarised statements derived from a threat assessment for which a physical protection system (PPS) is planned and designed. This article describes the development of a DBT for the Irradiation Facility at the Centre for Applied Radiation Science and Technology (CARST) in Mafikeng, based on its threat and its risk as a radioactive source. The purpose of the DBT was to serve as a threat assessment technique, providing a basis for planning a PPS by operators of the centre. A competent authority for nuclear security then gives approval for the implementation of the physical protection plan. The DBT assessment methodology is an International Atomic Energy Agency (IAEA) recommended method for designing security measures corresponding to the categories of radioactive sources. The higher the risk, the more secure the facility should be.

A Design Basis Threat (DBT) describes the summary of attributes and characteristics of potential insider and/or external lawbreakers, who might attempt sabotage or the unauthorised removal of nuclear or radioactive material, against which a physical protection system (PPS) should be designed.[1] Development of a DBT is important because it enables nuclear facility operators to protect and secure nuclear and other radioactive materials with associated facilities and activities. The International Atomic Energy Agency (IAEA), through its information circular on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev.4), described how to develop a notional DBT.[2] A number of IAEA member states, recognising the importance of the DBT tool, requested that workshops be organised and the method for development, maintainance and usage of a DBT be presented. In May 2009 148 states ratified the final document, which describes the processes for formulating a DBT.

Physical protection of facilities should be based on up-to-date evaluations of threats,

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encompassing all those identified by a state's security agencies.[3] These evaluations are formalised through a threat assessment process. A DBT can then be derived from this process to facilitate the development of protection mechanisms for the facility. A DBT describes the motivation, intentions and capabilities of potential lawbreakers and uses these to inform the protection systems. A DBT also describes the attributes and characteristics of potential insider (current employees at the facility) and outsider (a group of criminals or former disgruntled employees) lawbreakers who might plan or attempt a malicious act. These malicious acts may include unauthorised removal or sabotage of a facility's nuclear assets, which should be protected and secured through a designed and evaluated PPS. The DBT would also serve as a deterrent to a lawbreaker who wishes to carry out a malicious act, because of its use in the design and evaluation of PPS. It is therefore essential that a facility's protection is appropriate and that those with access to it have proper authorisation, in accordance with national laws and regulations, and the physical means to protect it.

This article describes the development of a DBT, and summarises the statements from the threat assessment for the Irradiation Facility at the Centre for Applied Radiation Science and Technology (CARST) in Mafikeng. It considers the consequences of a possible security event, such as unauthorised access or sabotage of the radioactive source housed in one of the centre's buildings, as well as the need for a well-designed and evaluated PPS.

Risk assessment

A risk assessment is a rational and orderly approach to problem identification and probability determination. It is a method for estimating the expected loss from the occurrence of an adverse event. Risk assessments will never be a precise methodology, because they are about estimation and probabilities.[4] CARST has at its disposal critical equipment used in its training and research work. In any security event affecting the assets of the facility, the centre stands the chance of suffering economic loss, since these assets are worth millions of rands. In addition, significant human and physical resources may be needed to decontaminate the centre after a possible breach.

Most irradiation facilities conduct routine risk assessments in order to determine if their security systems are adequate. Risk assessments produce different results for different facilities, but generally always consider the likelihood of a negative event, in this case a security incident and its consequences. Security risk can be measured using the equation:[5]

$$R=P_A \times (1-P_E) \times C \qquad (1)$$

where:

- R is the risk to the facility in the event of an adversary getting access to or stealing critical assets
- P_A is the probability of an attack during a particular period
- P_E is the effectiveness of the PPS against the identified threat
- $1-P_E$ is the vulnerability of the PPS against the identified threat
- C is the consequence value.[6]

The probability of an adversary attack during a particular period (P_A) can be very difficult to determine, but the probability ranges from 0 (no chance at all of an attack) to 1.0 (certainty of an attack). Critical assets, the loss of which would have serious consequences, still require protection if the P_A value is low, and so are still given high priority.[7]

Threat assessment

The threat assessment of a facility's assets and radioactive sources is the basis on which a DBT statement is formulated and a physical protection system designed. For the DBT of the CARST in Mafikeng, selected crimes recorded in close proximity to the centre (in towns A and B) over a three-year period were taken into account. This is because such crimes may be attempted and committed at the centre itself. An analysis of the possible consequences of unauthorised acquisition of the radioactive sources from CARST was performed.

Based on vulnerability analysis for specific sources, an assessment of the risk was made. The level of this risk determined the security measures required to protect the sources. The higher the risk, the more security capability is required. CARST is located on a university campus. The centre is located between an undergraduate residence and the Animal Health department of the university. The university is located in Town A, with Town B – the provincial capital – in close proximity. The centre has four permanent workers, two of whom live in Town A and two in Town B. Crime types considered a serious threat to the facility committed in and around towns A and B informed the DBT.

In the fairly recent past there have been a number of infiltrations of the Pelindaba nuclear research facility located outside Pretoria. A portable computer was stolen in 2005, while in 2007 a group of armed men broke into the facility at different points, deactivated a number of security layers, entered the control room for 45 minutes and escaped, but without removing any nuclear material.[8] In 2012 another violation of protective measures at the facility occurred and was described as an act of 'common' criminality.[9] The hundreds of kilograms of highly enriched uranium (HEU) held at the facility, which could be weaponised, may have been stored in 'locked-down' locations but the breaches remain a concern. Effective protection systems should deter adversaries from even attempting to access such facilities.[10] Instead, these infiltrations re-emphasise the need for a graded formulation of threats for all nuclear facilities, based on the potential harm that their uncontrolled nuclear material or radioactive sources can cause.

This is crucial, because nuclear hazards caused by the sabotage or unauthorised removal of nuclear materials and other radioactive materials can be devastating. Any possible criminality near such a facility must also be considered a threat to it.

The DBT on which this article is based considered selected crimes recorded in towns A and B. In 2013 towns A and B recorded 4 349 and 4 107 crimes respectively.[11] In 2014, 3 908 crimes were recorded in town A and 4 172 in town B.[12] In 2015, 4 395 crimes were recorded in town A and 4 139 in town B.[13] There are 78 towns and cities in the province in which towns A and B are located. Of these, towns A and B accounted for 86% and 58% respectively of the 12 selected crimes recorded in 45 police stations in the province, as presented in tables 1 and 2.

Although crime is notoriously difficult to measure, with crime reported to police offering only a partial view of actual crime types and rates, it is common practice to use official crime records to inform DBT analyses.[14]

The last national census in South Africa was carried out in 2011. It records a population of 38 297 for Town A and 291 500 for Town B. Statistics South Africa reports that the population growth rate from 2001–2011 was +1.17% per year. If the same is applied to Town A, its population in 2017 would be approximately 41 073, and Town B's 312 626.[15]

By using this data, together with police crime statistics, approximate crime rates can be calculated for each town, which can in turn inform the DBT.

Table 1: Selected crimes committed in Town A in 2013, 2014 and 2015

Crime	Town A, with yearly number of crimes, ranking by prevalence of crime type in the province (if in top 10 of province's 78 precincts) and crime rates per 100 000 residents								
	2013	Provincial prevalence ranking	Per 100 000 residents	2014	Provincial prevalence ranking	Per 100 000 residents	2015	Provincial prevalence ranking	Per 100 000 residents
Unlawful possession of fire arms and ammunition	4	N/A	**9.74**	21	6th	**51.13**	16	10th	**38.96**
Common robbery	110	5th	**267.82**	96	6th	**233.73**	108	4th	**262.95**
Robbery with aggravating circumstances	308	3rd	**803.45**	330	2nd	**803.45**	352	2nd	**857.01**
Malicious injury to property	333	3rd	**810.75**	220	6th	**535.63**	188	8th	**457.72**
Burglary at non-residential premises	135	10th	**328.68**	131	9th	**318.94**	172	7th	**418.77**
Drug-related crime	302	7th	**735.28**	385	8th	**937.35**	433	7th	**1 054.20**
Robbery at non-residential premises	83	1st	**202.08**	76	3rd	**185.03**	70	2nd	**170.43**
Kidnapping	9	8th	**21.91**	14	5th	**34.09**	8	N/A	**19.48**
Burglary at residential premises	844	4th	**2 054.88**	651	4th	**1 584.98**	920	2nd	**2 239.91**
Robbery at residential premises	77	3rd	**187.47**	82	2nd	**199.64**	108	1st	**262.95**
Crimen injuria (stalking)	54	6th	**131.47**	41	N/A	**99.82**	25	N/A	**60.87**
Carjacking	13	5th	**31.65**	15	3rd	**36.52**	7	N/A	**17.04**

Note: Crimen injuria is the act of unlawfully and intentionally impairing the dignity or privacy of another person. Stalking a person deprives him/her of privacy.

The crimes in the tables were selected due to their nature. Firearms and ammunition can be used to enter the centre. Robbery and burglary targeting the houses of centre employees may lead to the theft of vital information, keys or pass codes for entry to the centre. Crime committed at or against the centre could be carried out under the influence of drugs. Lawbreakers may stalk or kidnap an employee or their family member in order to extract information or to aid their entry to the centre. Vehicles stolen through carjacking may be used

Table 2: Selected crimes committed in Town B in 2013, 2014 and 2015

Crime	Town B, with yearly number of crimes, ranking by prevalence of crime type in the province (if in top 10 of province's 78 precincts) and crime rates per 100 000 residents								
	2013	Provincial prevalence ranking	Per 100 000 residents	2014	Provincial prevalence ranking	Per 100 000 residents	2015	Provincial prevalence ranking	Per 100 000 residents
Unlawful possession of fire arms and ammunition	9	N/A	**2.88**	8	N/A	**2.56**	15	N/A	**4.80**
Common robbery	164	2nd	**52.46**	133	2nd	**42.54**	114	2nd	**36.47**
Robbery with aggravating circumstances	205	6th	**65.57**	234	8th	**74.85**	236	7th	**75.49**
Malicious injury to property	260	5th	**85.57**	169	N/A	**54.06**	156	N/A	**49.90**
Burglary at non-residential premises	313	3rd	**100.12**	213	5th	**68.13**	268	4th	**85.73**
Drug-related crime	112	N/A	**35.83**	223	N/A	**71.33**	278	N/A	**88.92**
Robbery at non-residential premises	32	N/A	**10.24**	48	5th	**15.35**	50	5th	**16.00**
Kidnapping	19	1st	**6.08**	13	7th	**4.16**	9	8th	**2.88**
Burglary at residential premises	385	N/A	**123.15**	415	N/A	**132.75**	410	N/A	**131.15**
Robbery at residential premises	24	N/A	**7.68**	35	9th	**11.20**	34	N/A	**10.88**
Crimen injuria (stalking)	80	4th	**25.59**	46	8th	**14.71**	45	7th	**14.40**
Carjacking	9	9th	**2.88**	10	7th	**3.20**	5	N/A	**1.60**

to transport stolen items from the centre, or used in an attack on the centre. Because it can be very difficult to determine the probability of an attack (PA) at a particular time, records of these types of crimes help to determine criminal risk in the area.

Tables 1 and 2 illustrate a decrease in common robbery, malicious injury to property, burglary at non-residential premises and crimen injuria (stalking) from 2013 to 2014 in both Town A and Town B. In the same period there was an increase in robbery with aggravating circumstances, drug-related crime, carjacking and robbery at residential premises. Unlawful possession of arms and ammunition and kidnapping increased in Town A but decreased in Town B in 2014, while burglary at residential premises and robbery at non-residential premises decreased in Town A but increased in Town B in 2014, compared to 2013.

Again, the tables illustrate a decrease in carjacking, malicious injury to property, kidnapping and crimen injuria (stalking) from 2014 to 2015, in both Town A and Town B. In the same vein, burglary at non-residential premises, robbery with aggravating circumstances and drug-related crime all increased in 2015 in both towns. Burglary at residential premises, common robbery and robbery at residential premises increased in Town A but decreased in Town B in 2015, whilst the unlawful possession of arms and ammunition, and robbery at non-residential premises decreased in Town A and increased in Town B in 2015, compared to 2014.

Despite these fluctuations in reported crime, police in towns A and B recorded more crime than all but nine other precincts in the province. The tables show the number of crimes, each with its corresponding crime rate per 100 000 residents. Crime rates provide a more realistic picture of risk than do totals of recorded crime. In this case, the selected crimes were committed relatively consistently for the three-year period of the study.

Types and methods of lawbreakers

When formulating a DBT it is assumed that in any attack against a facility, there are three kinds of possible lawbreakers: outside lawbreakers (outsiders), inside lawbreakers (insiders who work at the facility) and outsiders working in collusion with insiders but not active in every attack.[16] Outsiders can be a group of criminals, terrorists or extremists. There are two types of insider lawbreakers: passive and active. Insiders can collude with outsiders to help them defeat protective layers of the PPS while under duress (e.g. a threat to the life of his/her family) or willingly (part of the criminals, or not happy with a decision taken by management).

There are three primary methods that lawbreakers may employ during an attack. One is deceit: the act or practice of deceiving someone by concealing or misrepresenting the facts. Stealth (movement that is quiet and careful in order not to be seen or heard, or a secret action) is another. The last method involves strength or energy as an attribute of physical action to coerce, especially with the use or threat of violence, commonly termed *force*.

Considering the nature and complexity of recorded crime in the towns surrounding the centre, including unlawful possession of firearms and ammunition, robbery with aggravating circumstances, robbery at residential and non-residential premises, and malicious damage to property, it is probable that all of these will involve the use of force. Deceit is more likely to form part of crimes such as common robbery, kidnapping and some crimen injuria, such as stalking. Stealth may be employed when entering premises to commit crimes such as burglary.

All three infiltrations that took place between 2005 and 2012 at the Pelindaba nuclear facility, South Africa's main nuclear research centre, run by the South African Nuclear Energy Corporation (NECSA), should inform the developer and evaluator of a DBT for CARST. The DBT should focus on the specific methods used by lawbreakers, and take into account technological advancements, in order to prevent future break-ins. In the 2005 infiltration, protection measures were breached, enabling entry into the facility and theft of a portable computer.[17] This breach could have been carried out by an outsider, or an outsider working in collusion with insiders. The lawbreakers might have defeated the security system by deceit – using false authorisations and identification – or by stealth – an insider defeating the detection systems and enabling outsiders to enter the facility covertly. These methods could also be employed by either of the groups of lawbreakers mentioned above.

In 2007 the lawbreakers probably used force to enter the facility, since they were armed, and managed to deactivate security layers and enter from different directions, in groups, simultaneously. There may also have been an element of stealth, since these armed men were able to penetrate the control room for a period of 45 minutes and escape without being detected. These attacks may have been masterminded by a certain group of people, e.g. criminal outsiders, disgruntled former or current employees, or a combination of the two.

Similarly, the third violation of protective measures at the facility in 2012, described as an act of 'common' criminality, might have used stealth by an insider or deceit by an outsider working in collusion with an insider. Outcomes of the investigations of these three infiltrations have not been made public, but in 2010 the Democratic Alliance (DA) wrote to the IAEA, asking it to ensure that South Africa's uranium stock, which can be used for nuclear weapons, was securely stored. DA spokesperson Pieter van Dalen asked the IAEA to help South Africa have its uranium downgraded. The party also asked the agency to get the South African government to disclose the outcome of an investigation into the 2007 security breach at Pelindaba, where the uranium was stored – but to no avail.[18]

Capabilities of lawbreakers

In formulating a DBT, it can be assumed that lawbreakers committing the above crimes may possess firearms and other tools like pliers, hacksaw blades, crowbars and knives. In addition to their own weapons and hand tools, they would probably use any other tool or piece of equipment found at the attacked premises that would facilitate their criminal objectives. Lawbreakers also use a range of transportation, including cars, trucks and helicopters, all of which must be taken into account.

The aftermath of past attacks (such as the sarin attack on the Tokyo subway in 1995, the attack on the World Trade Center in New York City in 2001, anthrax attacks in New York and Florida in 2001 and the Madrid and London train bombings in 2004 and 2005, respectively) has compelled security analysts – in particular nuclear security professionals – to include weapons of mass destruction as an emerging lawbreaker capability and threat. These weapons include chemical, biological, radiological or explosive materials that have the ability to cause mass casualties, public fear and lasting contamination.

The above information was used to guide the design of a PPS for CARST. It took into consideration all tactics, capabilities, types of attack and groups of people who might attack CARST, so as to put in place a PPS to protect the centre against these attacks.

Potential actions and motives of lawbreakers

When there is an attack at a facility, lawbreakers' actions depend mainly on their goals, such as theft, sabotage, terrorism and political protest.

The motives of lawbreakers might be ideological, economic, revenge (by former or current employees), or based on the belief that provincial leadership only responds to strike action and violence. In South Africa, and in the province where the centre is located, most crimes committed have to do with pride, masculinity, shame, upbringing, and a culture of violence at school and at home.[19] Even if lawbreakers are driven by ideology, they still expect to derive some self-fulfilment from their unlawful actions. Some Muslim extremists embrace martyrdom and sacrifice their lives to destroy and kill, in the belief that the afterlife holds sufficient reward, as promised in the Quran.[20] Certain companies pay criminals to destroy the facilities and equipment of others in the same line of business. Personal vendettas might lead lawbreakers to covertly steal vital information with the intention to blackmail and destroy reputations.

Results: Design Basis Threat statements

According to the IAEA's Code of Conduct, a categorisation system for radioactive sources should be maintained so that measures to control and secure are commensurate with the radiological risks.[21] This categorisation system is based on the potential that radioactive sources have to cause deterministic health effects, which only appear after threshold values are exceeded and for which the severity of effect increases with an increasing dose beyond the threshold. The value of the source's activity (A), divided by its dangerous value (D), determines the category and the extent of damage it can cause. A radioactive material can be said to be 'dangerous' if it can cause permanent injury or be immediately life threatening if not managed safely and securely. Radioactive sources are grouped into five categories; category one being the most dangerous.

In the two towns surrounding CARST there is a significant amount of criminal activity during the day and at night. Communities know of the university and its facilities, including the irradiator and other equipment, but there has been little formal interest in it to date other than from students and researchers.

There have been two organised protests at the university, in 2008 and 2015. Student activists and others protested and vandalised grocery and computer accessory shops on one of the three campuses of the university. The two protests received a great deal of media attention. The student activists were able to drive the university security guards off the campus and the police were only contacted once the university had been forced to close.

Based on the above assessment, the designer of a physical protection system of nuclear facilities housing category 1–3 radioactive sources should consider the determination, violent nature and methods of both potential insider and outsider lawbreakers, either by stealth or deceptive actions. These considerations should also be applied to a minimum of two to three lawbreakers who may attack at any time during the day or night, with determination and violence. The following should be noted:

- Insider lawbreakers may be trained and possess skills in handling radioactive material. They may also have hand tools to help them break through barriers or assist an outsider to do so.
- Knowledgeable individuals who work in the facilities may provide insider assistance in an attempt to participate in a more passive role, for instance, facilitating entrance and exit, disabling alarms and communications, and participating in non-violent attacks. Such internal threats can arise from any employee in any of the positions at the facility.
- The conspiracy between individuals in the facility and outsiders may entail access to and detailed knowledge of nuclear power plants or other nuclear facilities, and/or items that could facilitate theft of nuclear materials – for example, small tools, false documents, facility keys and pass codes and substitute nuclear material.
- Lawbreakers' weapons, which the PPS and the security response team should be able to

overcome or counter, will likely include pistols, since there are a number of crimes involving the unlawful possession of firearms and ammunition in surrounding towns.

- Lawbreakers will most probably have access to vehicles, from either carjacking or rentals, for transporting radioactive materials from the site. Specialist vehicles are normally used for transporting radioactive materials, but lawbreakers may not be aware of the risk associated with transporting a radioactive source close to their bodies.

Conclusion

A DBT statement is essential when designing a PPS, from the threat assessment to the facility's assets. In the threat assessment conducted for CARST, attention was duly given to crimes recorded in the surrounding towns. There is a high risk of contamination and unwarranted radiation exposure if there is a security breach at the centre. This would become a financial burden for the country and the university, since significant resources would be needed for decontamination and the treatment of anyone exposed to harmful materials or radiation. The three successful infiltrations at Pelindaba illustrate that any nuclear facility is at risk, including CARST. Because it is difficult to ascertain exactly when a lawbreaker might attack a facility (see Equation 1), security experts must consider all the consequences of a potential breach. If the consequence is serious, then the risk is also serious. The DBT statements that were derived from the CARST threat assessment enable policymakers and security agencies to make informed decisions in designing and evaluating their physical protection systems. These assessments and DBT statements also enable the competent authority for nuclear security to consider which PPS to approve when applications are made.

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Notes

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